

Gilligan, the Skipper, and a Three-Hour Tour!

FOCUS

The effects of wind and currents on navigation

GRADE LEVEL

9-12 (Physical Science)

FOCUS QUESTION

What variables must be taken into account by a ship's captain when traveling on the ocean?

LEARNING OBJECTIVES

Students will be able to use dimensional analysis (factor-label) to convert units.

Students will be able to read a scale on a map and determine distances from point to point.

Students will use knowledge of vectors to calculate resultant velocities.

Students will use simple algebra and the velocity equation ($V = \text{distance}/\text{time}$) to solve for velocity, distance, and/or time.

ADDITIONAL INFORMATION FOR TEACHERS OF DEAF STUDENTS

In addition to the words listed as Key Words, the following words should be part of the vocabulary list.

Variable
Magnitude
Direction
Resultant vector

The words listed as key words should be introduced prior to the activity. There are no formal signs in American Sign Language for any of

these words and many are difficult to lipread. If some of this information has not already been covered in your class, you may need to add an additional class period to teach vocabulary and teach some of the Background Information to the students prior to the activity.

MATERIALS (Per group of students)

- ☐ Student Activity Sheet, one per student
- ☐ Map of prospective dive sites
- ☐ Meter stick
- ☐ Ruler
- ☐ Stopwatch
- ☐ Small battery-powered toy car
- ☐ 3-4 meter sheet of butcher paper (needs to be approximately one meter wide)
- ☐ Tape

A/V MATERIALS

None

TEACHING TIME

One 90-minute class period

SEATING ARRANGEMENT

Groups of 3-4 students

MAXIMUM NUMBER OF STUDENTS

Variable, depending on available materials

KEY WORDS

Knots
Velocity
Vector
Displacement

Distance
Component
Nautical mile
Statute mile

BACKGROUND INFORMATION

Students will be required to have prior knowledge of dimensional analysis. When converting units, dimensional analysis or factor-labeling is used. This is a visual way of canceling out undesired units and arriving at desired units. Conversion factors are simple equivalencies used to convert. Students should be reminded that conversion factors are always equal to one and are reversible. Here is an example for converting miles to meters.

$$1.75 \text{ miles} \left| \frac{5280 \cancel{\text{ft}}}{1 \text{ mile}} \right| \left| \frac{1 \text{ meter}}{3.28 \cancel{\text{ft}}} \right| = 2817 \approx 2820 \text{ meters}$$

*Notice how each unit is cancelled out by the unit on the bottom of the next bracket. This is essential for students to remember. It is also important to note that the final answer is rounded to three significant figures because the initial number is in three significant figures. Of course, it is also possible to solve this problem using different conversion factors. See the example below:

$$1.75 \text{ miles} \left| \frac{1760 \cancel{\text{yd}}}{1 \text{ mile}} \right| \left| \frac{1 \text{ meter}}{1.094 \cancel{\text{yd}}} \right| = 2815 \approx 2820 \text{ meters}$$

Students must also have a good understanding of vectors to solve several problems in this activity. A vector quantity is defined as a variable having both magnitude and direction. The quantities that are added together are

called component vectors, while the end product is called the resultant vector. Vector problems can be solved both graphically and analytically. For this activity, it is easiest to solve the problems analytically, but it will also help to have diagrams.

Vector problems should be solved using the "Tail to Tip" method.

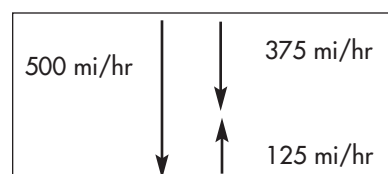
"Tail to Tip" Method

1. Draw and label the first vector. Be sure it is going in the proper direction.
2. Draw and label the second vector beginning at the tip of the original vector. (In this example, the vectors will be offset slightly to make them easier to see.)
3. Continue to repeat Step 2 for all component vectors. (In this activity there will be only two components for each problem.)
4. To draw the resultant vector, begin at the tail of the first vector and draw a line to the tip of the last vector.

Here is an example with the proper steps:

Ex: A plane is flying due south at 500 miles/hour, while a headwind is blowing due north at 125 miles/hour. What is the resultant velocity of the plane?

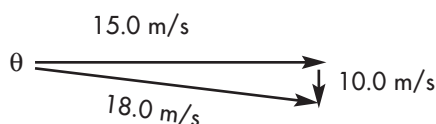
Solution



Answer: The resultant velocity of the plane is 375 miles/hour, south. Use subtraction to solve this one-dimensional problem. If the wind and plane were going in the same direction, it would be necessary to add the two components.

If the two (or more) component vectors are not in one dimension, it becomes necessary to use trigonometry. Students will need to be familiar with the Pythagorean Theorem and the three common trigonometry functions: sine, cosine, and tangent. Here is an example problem:

Ex. A boat travels at 15.0 m/s east on the ocean. The surface current flows south at 10.0 m/s. What is the boat's resultant velocity?



To solve for the magnitude of the resultant vector, use the Pythagorean Theorem:

$$R = \sqrt{15.0^2 + 10.0^2}$$

$$R = 18.0 \text{ m/s}$$

Use trigonometry to find the angle:

$$\theta = \tan^{-1}\left(\frac{10.0}{15.0}\right)$$

$$\theta = 34^\circ$$

Answer: The resultant velocity of the boat is 18.0 m/s, 34° south of east.

LEARNING PROCEDURE

Note: This activity is designed to be specifically related to the activities of the crew of the *Seward Johnson II* during the South Atlantic Bight Expedition which took place in July/August of 2002.

1. Pose the following problem to the students: Imagine that you are the captain of the *Seward Johnson II* on the South Atlantic Bight Expedition in July/August 2002. It is your responsibility to get the science team through the seven planned dive stops. The *Seward Johnson II* is 204-feet long and displaces 781 tons. It was built in 1982 and is maintained by the Harbor Branch Oceanographic Institution. It is capable of a cruising speed of 11 knots.
2. Hand the Student Activity Sheet out to students and have them work through each station.
3. Write the following conversion factors on the board:
1 nautical mile = 1.1516 statute miles
1 knot = 1 nautical mile/hour or 1 knot = 1.1516 statute mile/hour

Statute Mile: An Imperial unit of length also called the statute mile and equal to 5280 feet. It is also equal to $(5280)(12)(2.54)/105 = 1.60934 =$ kilometers. (From <http://scienceworld.wolfram.com/physics/Mile.html>)

Nautical Mile: A unit of length equal to the distance along 1 arc minute of latitude at

the Earth's equator. It is used in navigation, and is defined as 6076.103 feet, or 1.15078 (statute) miles. (From <http://scienceworld.wolfram.com/physics/Mile.html>)

THE BRIDGE CONNECTION

<http://www.vims.edu/bridge/physics>

THE "ME" CONNECTION

Have students research to find out what education and background is necessary to become a captain on a research vessel like the *Seward Johnson II*.

CONNECTIONS TO OTHER SUBJECTS

Physics, Algebra, Geometry

EVALUATION

Have students turn in their Student Activity Sheet to be evaluated by the instructor.

EXTENSIONS

Track the progress of the *Seward Johnson II* on the website <http://www.oceanexplorer.noaa.gov>. Students can also be required to research one or more of the research vessels found on the web page above.

RESOURCES

<http://www.oceanexplorer.noaa.gov>.

<http://scienceworld.wolfram.com/physics/mile.html>

NATIONAL SCIENCE EDUCATION STANDARDS

Content Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science

- Motions and forces

Activity developed by Jeff Walker, Hanahan High School, Charleston, SC

Student Activity Sheet

Station 1: The initial leg of your voyage will be from Ft. Pierce, FL to the first dive site at the Savannah Scarp (31.53 N, 79.74 W). The distance of this trip is 247 nautical miles. Convert this distance, using dimensional analysis, to statute miles and then to kilometers.

Assume a cruising speed of 11 knots. Convert this speed to kilometers per hour. If you leave Ft. Pierce at 10:30 am and maintain the same cruising speed, calculate what time you should arrive at the Savannah Scarp.

Complete the following activity before continuing to Station 2:

Set your battery-powered toy car on the end of your long piece of paper. Imagine that the car is your ship and the paper is the jet stream of moving ocean water. Mark two points 2.0 meters apart on the floor. Place the paper next to these points and place your car on the paper next to the first mark. Without moving the paper, time in seconds (using the stopwatch) how long it takes the car to move from the first mark to the second mark and record the time below. Now repeat the experiment while moving the paper in the direction of the car and record the time below. Did the car make the trip from mark to mark faster or slower? Why?

Time without moving paper: _____ seconds

Time with paper moving in direction of car: _____ seconds

Now, start the car from the first mark and move the paper in the opposite direction. Did the car make the trip from mark to mark faster or slower? Why?
Time with paper moving in opposite direction of car: _____ seconds

Station 2: The second leg of your trip will be from the Savannah Scarp to the GA Tilefish Grounds (31.73 N, 79.39 W). Using the map provided and the scale at the bottom of the map, determine the distance for this leg of the trip in kilometers. Assume that the Tilefish Grounds are to your immediate north. Calculate how long it will take you to traverse this leg. BUT WAIT, the Jet Stream happens to be flowing directly north at 2.2 km/hr today. You must include this velocity into your calculations. Refer to the activity above if you have a hard time deciding how to approach this problem.

Station 3: The third leg of your trip will be from the GA Tilefish Grounds to Julian's Ridge (32.35 N, 79.05 W). If the distance between these two sites is 40.8 nautical miles and it takes you 4 hrs 35 minutes to arrive on station, what average speed did you travel in knots?

Station 4: The fourth leg of the trip is from Julian's Ridge to the SC Tilefish Grounds (32.49 N, 78.65 W). Using the map and scale at the bottom of the map, determine the distance between these two sites in statute miles. Assuming the ship travels a constant 11 knots, calculate how long this leg of the trip will take.

Station 5: The fifth leg of the trip will be from the SC Tilefish Grounds to the Charleston Bump (32.63 N, 78.3 W). Assuming the trip is exactly 19.56 nautical miles, calculate the distance in kilometers. On this day, you happen to be heading directly into a headwind that averages a speed of about 5.0 knots. Assume the vessel is capable of its standard 11 knots, while remembering the headwind. Find the vessel's resultant velocity and calculate how long it will take to complete this leg of the trip.

Activity: Place your battery-powered toy car on the paper so that it will travel a perpendicular line across the paper. Make a mark on the floor directly across from the toy car. Let the car go and watch as it hits the mark. Now, repeat this experiment with someone pulling the paper at a constant velocity. Notice that the car probably did not hit the mark. Play around with the angle of the car to ensure that it hits the mark. In the space below, describe the direction you pointed the car to make it arrive at the mark.

Station 6: The last stop is almost directly to your north. For this last activity, we will assume Georgetown Hole is directly to your north. As you travel toward Georgetown Hole (32.85 N, 78.25 W), you experience a current of about 8 knots that is traveling due east. This current is produced by the Jet Stream being affected by the Charleston Bump (a geologic feature off the coast of SC). The current will push your vessel far to the east unless you calculate and travel toward the west to counteract the easterly push. Using the "Tip to Tail" method of adding vectors, calculate the angle that you will have to point the vessel in order to ensure you end up exactly at Georgetown Hole.

Station 7: Displacement is defined as initial position minus final position. It is considered to be a vector quantity while distance is considered to be scalar. Using the map as a guide, find the total distance the *Seward Johnson II* traveled from Savannah Scarp to Georgetown Hole. Show your work below. Now, find the displacement of the *Seward Johnson II*. Show your work below. (Hint: displacement is "as the crow flies" and distance is your actual pathway.)

Student Activity Sheet Key

1.

$$247 \text{ nm} \left| \frac{1.1516 \text{ miles}}{1 \text{ nm}} \right| \left| \frac{1.6093 \text{ km}}{1 \text{ mile}} \right| = 481 \text{ km}$$

$$11.0 \text{ knots} \left| \frac{1 \text{ nm}}{1 \text{ hr}} \right| \left| \frac{1.1516 \text{ miles}}{1 \text{ nm}} \right| \left| \frac{1.6093 \text{ km}}{1 \text{ mile}} \right| = 20.4 \text{ km/hr}$$

$$D = V \times T \text{ so } T = D \div V$$

$$T = \frac{481 \text{ km}}{20.4 \text{ km/hr}} = 23.6 \text{ hr}$$

$$0.6 \text{ hr} = \frac{60 \text{ min}}{1 \text{ hr}} = 36 \text{ min}$$

$$10:30 \text{ am} + 23 \text{ hrs } 36 \text{ min} = 10:06 \text{ am}$$

2. Approximate distance = 40 kilometers (Student answers may vary.)

$$V_{\text{res}} = V_{\text{ship}} + V_{\text{Jet Stream}}$$

$$V_{\text{res}} = 20.4 + 2.2 = 22.6 \text{ km/hr}$$

$$T = D \div V$$

$$T = \frac{40 \text{ km}}{22.6 \text{ km/hr}} = 1.8 \text{ hr}$$

$$0.8 \text{ hr} = \frac{60 \text{ min}}{1 \text{ hr}} = 48 \text{ min}$$

$$1 \text{ hr } 48 \text{ min}$$

3. $V = D \div T$

$$V = \frac{40.8 \text{ nm}}{4.6 \text{ hr}} = 8.9 \text{ kn}$$

4. Approximate distance = 44 km

Remember from Problem #1 that 11 knots = 20.4 km/hr

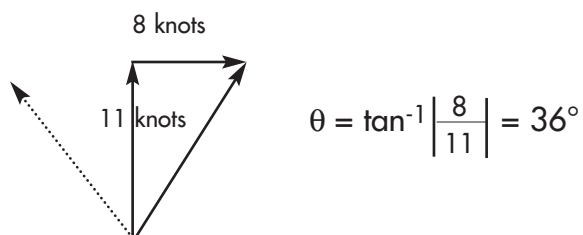
$$T = D \div V \text{ so } \frac{44 \text{ km}}{20.4 \text{ km/hr}} = 2.16 \text{ hr} \quad 0.16 \text{ hr} \left| \frac{60 \text{ min}}{1 \text{ hr}} \right| = 10 \text{ min}$$

$$\text{Time} = 2 \text{ hrs } 10 \text{ minutes}$$

$$\begin{aligned} 5. \quad V_{\text{res}} &= V_{\text{ship}} - V_{\text{wind}} \\ V_{\text{res}} &= 11.0 \text{ knots} - 5.0 \text{ knots} \\ V_{\text{res}} &= 6.0 \text{ knots} \end{aligned}$$

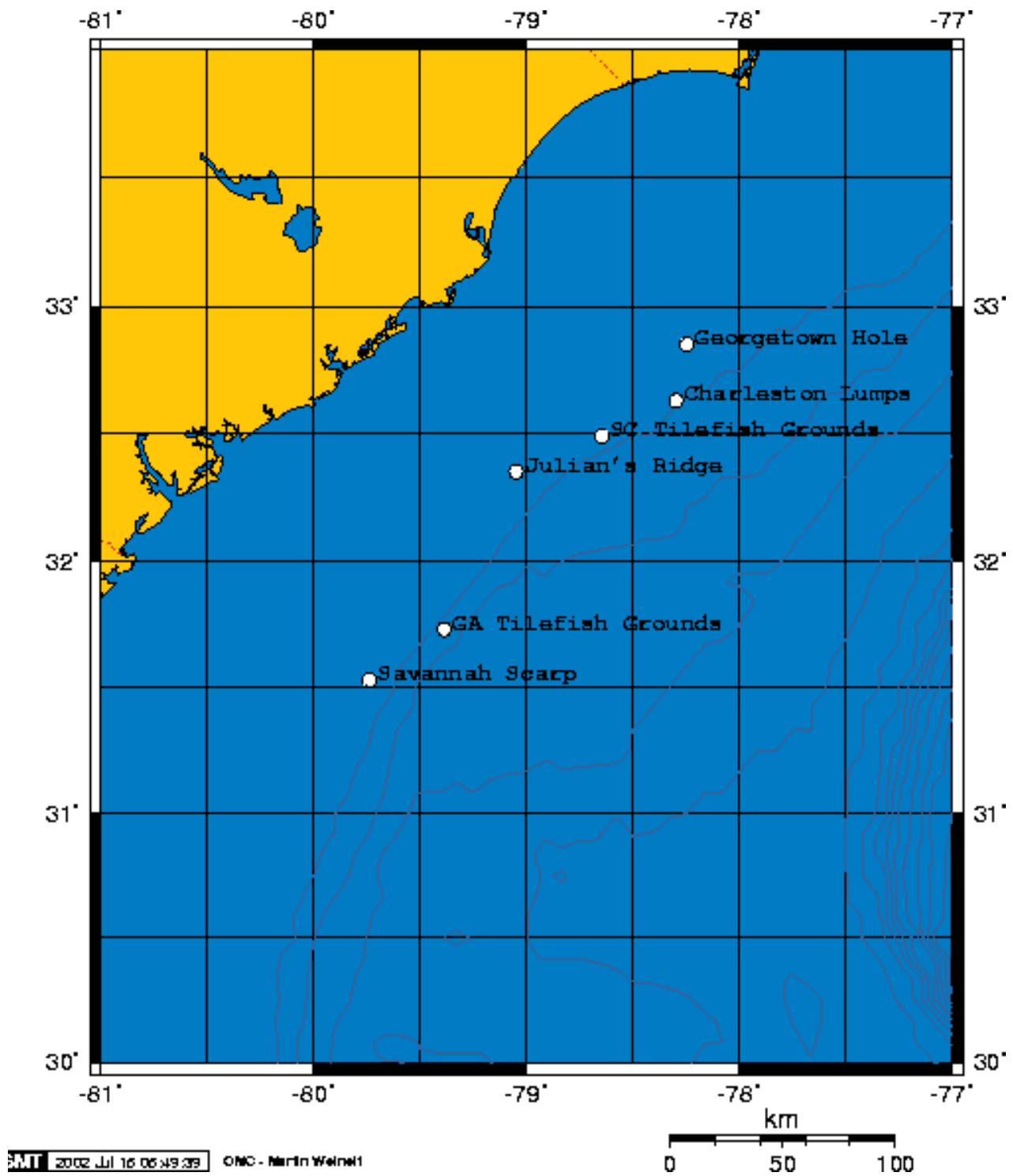
$$T = D \div V \quad \text{so} \quad \frac{19.56 \text{ nm}}{6 \text{ kn}} = 3.26 \text{ hr}$$

6. Be sure calculator is in degrees mode!!!!
To counteract the crosswind, the vessel should be steered 36° west of North. See dotted line on diagram.



7. Distance: approximately 218 km
Displacement: approximately 200 km

Prospective Dive Sites
Islands in the Stream 2002



NOTES/THOUGHTS/INSPIRATIONS

[illegible]